Hazardous Air Pollutant Emissions

From On-Road Mobile Sources In Huntsville, Alabama

June 2004

Division of Natural Resources & Environmental Management

DNR AQEI/ 06-04

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I. INTRODUCTION

A. Overview and Background Information

The Huntsville Division of Natural Resources (DNR) was awarded $50,000 in § 105 Grant funding by EPA Region 4 to conduct a number of air toxics characterization activities in Fiscal Years 2003 and 2004.[1] This supplemental grant allowed Huntsville to build on the Hazardous Air Pollutant (HAP) emissions inventory work that had been completed under a previous air toxics characterization grant. Components of the work plan for this supplemental grant included 1.) updating and performance of additional quality assurance activities for the area source emissions inventory developed under the previous award; 2.) conducting detailed HAP emissions modeling of the POTWs (Publicly Owned Treatment Works) in Huntsville; 3.) performing screening level dispersion modeling for a number of area sources of HAP emissions; and 4.) updating and refining the mobile source HAP emissions inventory developed under the previous air toxics characterization grant.[2] This Report presents the mobile source HAP emissions inventory work performed pursuant to the Grant Agreement.

Although DNR has maintained and periodically updated an on-road mobile source emissions inventory for criteria pollutants[3] for many years, an inventory of mobile source HAP emissions was not developed until 2001.[4] In developing this initial mobile source HAP inventory, MOBTOX5b, a toxic pollutant emission factor model, was used to estimate HAP emissions of acetaldehyde, benzene 1,3-butadiene, and formaldehyde from on-road mobile sources in the Huntsville area. PART5, a particulate emission factor model, was used to estimate diesel particulate emissions. The emissions factors obtained using these models were based on local vehicle registration data, fuel characteristics and climatological data, and these factors were coupled with local VMT (Vehicle Miles Traveled) information to develop the inventory.

Subsequent to development of Huntsville's mobile source HAP emissions inventory, EPA completed the task of updating and expanding the functionality of the MOBILE emissions factor model.[5] In addition to criteria pollutant emissions factors, the updated model (MOBILE6.1 and 6.2) calculates emission factors for particulate matter and six hazardous air

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[1] § 105 of the Clean Air Act authorizes EPA to make grant awards for state and local air pollution control program support. See 42 USC § 7405.

[2] The Work Plan is presented in detail in "Proposal for FY 2002 § 105 Grant Funds for Use in Air Toxics Characterization, " forwarded to Mr. Doug Neeley of Region 4's Air Radiation & Technology Branch under cover of Mr. D. Shea's April 15, 2002 transmittal letter.

[3] "Criteria pollutants" are those pollutants for which EPA has promulgated National Ambient Air Quality Standards (NAAQS). The criteria pollutants are ozone, sulfur dioxide, carbon monoxide, nitrogen oxides, lead and particulate matter (consisting of both "fine particles" and "coarse particles").

[4] Reference *Mobile Source Air Toxics Emissions Data: 1996 and 1999*; Division of Natural Resources and Environmental Management; DNR AQEI/08-01; August 2001. This report was forwarded to Ms. K. Prince of Regions 4's Air Planning Branch under cover of Mr. D. Shea's August 6, 2001 transmittal letter.

[5] The MOBILE model provides emissions factors for criteria pollutants and has been routinely used by air pollution control agencies in the development of mobile source criteria pollutant emissions inventories.

pollutants. Thus, the current version of MOBILE consolidates the functions previously performed by a cluster of mobile source emissions models.

The initial work in developing a HAP mobile source inventory resulted in on-road mobile source HAP emissions estimates for the years 1996 and 1999. This report presents the development of on-road mobile source HAP emissions estimates for 2002 using MOBILE6.1 and 6.2. In addition, DNR used the model to recalculate emission estimates for year 1999 using the same inputs that were initially used in the MOBTOX5b and PART5 models. By using the same inputs in the updated MOBILE model, a direct comparison of the models could be made, and DNR could evaluate directional differences attributable solely to the use of MOBILE6.1/ 6.2.

B. Scope of Modeling Effort

The on-road mobile source HAP emission modeling effort consisted of two parts. The first part consisted of repeating the modeling done for 1999 using MOBILE6.1 /6.2 using the same model inputs as those previously used in the MOBTOX5b model. However, in so doing, it was necessary to modify the characterization of the vehicle fleet, i.e. the VMT fleet mix. This is because MOBILE6.1 /6.2 differs substantially from prior versions of the MOBILE model in the structure of the input files, and uses a larger number of vehicle classes. The procedures outlined in Chapter 5 of the Users Manual (Converting MOBILE5 Inputs to MOBILE6) were used to convert the VMT fleet mix inputs used in the MOBTOX5b model to the required MOBILE6 format. [6] The resultant emission estimates were compared to the estimates obtained using the MOBTOX5b and PART5 models.

Part two of the modeling effort consisted of updating and refining the emission estimates for the on-road mobile source sector of the emissions inventory for year 2002. Inputs to the model included local VMT fleet mix, meteorology, fuel RVP and other required fuel parameters. Transportation network modeled speeds and road classifications, as determined by the City's Planning Department, were also used as inputs to the model. MOBILE6.1 /6.2 contains more flexibility with respect to model inputs, and allows for better characterization of mobile source emissions in the Huntsville area.

II. METHODS

A. Estimation of Vehicle Miles Traveled (VMT)

Local traffic count data are updated by the City's Engineering Department biennially, and DNR uses these traffic count data as the basis for estimating Huntsville's average daily VMT (Vehicle Miles Traveled). The 1999, 2001 and 2003 estimates shown in Table I are based on traffic counts made in these respective year(s). (VMT estimates developed using these traffic count data are identified in Table I as "Huntsville VMT"). The 2002 estimate shown in Table I was calculated as the mean of the 2001 and 2003 estimates, and is used as part of a QA (Quality

[6] *User's Guide to MOBILE6.1 and MOBILE6.2: Mobile Source Emission Factor Model;* EPA420-R-03-010; USEPA, Office of Air & Radiation; August 2003.

Assurance) check of the traffic count-based VMT estimates, as discussed below. However, in developing the on-road mobile source HAP emissions inventory for 2002, the 2003 VMT estimates were utilized rather than the 2002 VMT estimate shown in the Table. In other words, in order to conservatively estimate emissions for year 2002, DNR used VMT estimates based on the most current traffic count data, i.e. year 2003. Supporting documentation for the 2003 VMT estimates are included in Appendix A.

VMT estimates for the urbanized area[7] are developed by the City's Planning Department as part of the transportation planning process.[8] These data are published in the Federal Highway Administration Statistical Data publications as "Miles and Daily Vehicle Miles of Travel,"[9] and are included in Table I for comparative purposes. Daily VMT estimates for Madison County were obtained from the Alabama Department of Transportation (ALDOT) and are also shown in Table I.

Table I - Average Daily VMT (Huntsville, Urbanized Area & Madison County)

Year	Huntsville VMT	VMT based on Fuel Tax Revenue*	%D (QA-Check)	Urbanized Area VMT	Madison County VMT (ALDOT)	VMT based On Fuel Tax Revenue*	%D (QA-Check)
1999	4,772,294	4,825,595	1.1%	5,593,000	6,344,419	7,729,528	21.8%
2001	5,018,015			5,520,000	6,278,289		
2002	5,079,458	4,806,594	- 5.4%	5,714,000	7,943,851	7,969,042	0.3%
2003	5,140,900			5,888,199	--------		

The 2002 VMT estimate shown is the mean of the 2001 and 2003 estimates. (Traffic count data are updated biennially). Spreadsheet calculations of VMT estimates for year 2003 are included in Appendix A.

*Based on fuel tax revenue, local VMT fleet mix and fuel economy data.

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[7] The Huntsville Urbanized Area, for transportation planning purposes, is defined in the *Huntsville Area Transportation Study*. This document is accessible electronically from the Planning Department's website at http://www.ci.huntsville.al.us/Planning/mpo.htm. The urbanized area includes the municipalities of Huntsville, Madison, Triana, and Gurley, as well as intervening portions of Madison County.

[8] The City of Huntsville Planning Department is the lead agency in the Technical Coordinating Committee, which advises the Metropolitan Planning Organization (MPO) and performs the necessary technical and administrative tasks, such as transportation modeling, development of the Long-Range Transportation Plan and the Transportation Improvement Program. These transportation plans can be accessed electronically at the Planning Department's website http://www.ci.huntsville.al.us/Planning/mpo.htm.

[9] Reference (for 2002) www.fhwa.dot.gov/policy/ohim/hs02/pdf/hm71.pdf

As a QA check of the traffic count-based VMT estimates, DNR used vehicle registration, fuel tax revenue, and vehicle fuel economy data to estimate Huntsville's average daily VMT for year 2002 using procedures outlined in an EIIP (Emissions Inventory Improvement Program) document.[10] This approach was used both for the area within the corporate limits of Huntsville ("Huntsville VMT"), and for Madison County ("Madison County VMT"), as shown in Table I. Based on this methodology, the VMT estimate obtained for year 2002 differs by – 5.4% from the traffic count-based estimate for the Huntsville VMT, and agrees almost perfectly (% Difference = 0.3 %) for the Madison County VMT. These results are shown in Table I as the columns labeled "%D QA – check." Some of the difference reflected in the two estimates for the Huntsville VMT may be the result of work related commutes from surrounding communities into the City of Huntsville. These vehicle miles would be captured in traffic counts although a portion of the fuel purchases would likely be made outside the Huntsville City Limits and would not be reflected in Huntsville gasoline tax revenues.

As noted above, for 2002 the Madison County VMT estimates provided by ALDOT agree almost perfectly with the VMT estimate based on Madison County fuel tax revenue. Agreement within less than 0.5 % is rather remarkable, and suggests that the estimate is probably accurate. However, the increase of more than 1.5 million average daily VMT from year 2001 to 2002 demands some explanation of the ALDOT estimates. According to ALDOT, the increase is likely due to the inclusion of Federal roads in the 2002 data. Prior to 2002 these roads reportedly had not been included in the average DVMT county level estimates. This serves to explain the large discrepancy between the ALDOT VMT estimate and the VMT estimate based on County fuel tax revenues in 1999 as well. The ALDOT VMT data for 2003 were not available at the time the information in Table I was assembled. The supporting documentation for the 'QA-check' calculations for year 2002, are also included in Appendix A.

B. DEVELOPMENT OF MOBILE6.1 /6.2 Input Data

1. <u>VMT Fleet Mix and Age Distributions</u>

The VMT fleet mix used in the MOBTOX5b modeling for year 1999 was based on Madison County 1999 vehicle registration data. Since the Madison County registration data only included four categories of vehicles, these categories had to be expanded to represent the eight vehicle classes employed as MOBTOX5b inputs. At the time the initial on-road HAP emissions inventory was developed, this was done using the then projected MOBILE6 default fleet mix for 1999, with gasoline and diesel fueled vehicles represented separately. The methodology employed in expanding the four vehicle classifications to eight is described in detail in the 2001 Mobile Source Air Toxics Emissions technical report prepared by DNR.[11]

MOBILE6 has expanded the number of vehicle classes even further. Consequently, in performing the most recent mobile source emission factor modeling for the fleet in the Huntsville

[10] *EIIP Volume IV: Mobile Sources Preferred and Alternative Methods*. EPA-454/R-97-004d. July 1997

[11] See Footnote 4, *supra.*

area, vehicle class input data consisted of 16 combined gasoline and diesel vehicle classes. As noted previously, this further expansion of the vehicle classifications was effected using the procedures outlined in Chapter 5 of the MOBILE6 Users Manual (Converting MOBILE5 Inputs to MOBILE6).[12] The supporting documentation for these calculations can be found in Appendix B. Although this approach allowed conversion of the vehicle class information to the necessary MOBILE6 input format, there were no corresponding procedures for converting the age distribution data used in the MOBTOX5b modeling. Therefore, the MOBILE6 default age distribution data were used. The default age distribution data used in MOBILE6 can be found in the Fleet Characterization Technical Report.[13] A review of the data contained in the Report indicates a close correlation with the age distribution data previously used by EPA in the MOBTOX5b input files for the SE.[14]

Madison County vehicle registration data for year 2002 were employed in development of the updated on-road mobile source HAP emissions inventory. However, the registration data includes 11 classes of vehicles,[15] and these vehicle classes do not correspond to the 16 vehicle classes employed in the MOBILE6 input files. For example, the registration data included vans and small Sport Utility Vehicles (SUVs) in the passenger car category, whereas the MOBILE6 classifications apparently include these vehicle types as light duty trucks. Additionally, the County's light and medium truck category appeared to include some vehicles over 6000 pounds. Consequently, it was necessary for DNR to convert the local registration classification data to the MOBILE6 vehicle classification system. This was done by pooling Madison County vehicle classes such that the combined classes included all of the vehicles in a subset of the MOBILE6 vehicle classes. In other words, although individual vehicle registration classes do not correspond to those used in MOBILE, groups of registration data vehicle classes could be selected such that the pooled classes included all of the vehicles in a subset of the MOBILE6 vehicle classes, and no others. The fractional total of the vehicle registration cluster of classes was then compared to the fractional total of the corresponding cluster of MOBILE6 vehicle classes, and a ratio was determined. This ratio was in turn used to distribute the vehicles included in the cluster of vehicle registration classes among the corresponding MOBILE model vehicle categories using the MOBILE6 default distributions. For those individual vehicle classes in the registration data that directly corresponded to a MOBILE6 vehicle class, e.g. motorcycles, the local vehicle mix data were used without having to aggregate and redistribute the vehicle types into the MOBILE classifications. The calculations used to convert the local registration vehicle class data into the

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[12] See Footnote 6, *supra.*

[13] *Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates and Projected Vehicle Counts for Use in MOBILE6*; EPA 4520-P-99-011; USEPA, Office of Air & Radiation; April 1999.

[14] As part of the National Air Toxics Assessment (NATA), EPA had performed county-level mobile source HAP emissions modeling for year 1996, using MOBTOX5b and PART5. The input files used for the Southeast were provided to DNR at the time the initial on-road mobile source HAP emissions inventory was developed. (See DNR's 2001 Report on Mobile Source HAP Emissions, referenced in footnote 4, *supra*).

[15] At the request of DNR, the County's vehicle registration office manipulated their database and were able to expand the vehicle registration information to include 11 vehicle classes, a significant increase over the four vehicle categories included in previous registration summaries provided to DNR for purposes of emissions inventory development.

format required by MOBILE6 can be found in Appendix B. DNR used the MOBILE6 default age distribution data in the 2002 modeling.

2. Road Classifications & Speed Inputs

In the 1999 MOBTOX5b modeling, an average transportation network travel speed of 19.6 mph was used in the model. This was the default network speed that EPA had previously used for the Southeastern U.S. when using MOBTOX5b to estimate mobile source HAP emissions at the county level. The same average network travel speed was employed in the 1999 MOBILE6 modeling. In accordance with the MOBILE6 Users Guide, if the default MOBILE5 speed of 19.6 mph is being used, there is no required speed input and therefore no conversions or adjustments are required. Road classifications were not a required input in the MOBTOX5b model.

For the 2002 modeling, a Road Functional Classification Map of the Huntsville Urban area was obtained from the City's Planning Department and served as the basis for the classifications assigned to roadways for emissions modeling purposes. (Reference the spreadsheet calculation of average daily VMT contained in Appendix A – Road Classifications). The Planning Department Transportation Network Modeling provided the average speeds used as model inputs for collectors, arterials, etc. Collectors were modeled (as arterials) at the transportation network modeled speed of 34.8 mph. Arterials were modeled at the average network modeled speed of 37.4 mph. Local roads are not included in the transportation model, and no transportation network modeled speed was available. Therefore, for purposes of emissions factor development the local roads were modeled at the 12.9 mph MOBILE6 default. In MOBILE6 collectors and arterials are modeled as a single classification.

The supporting documentation for these model inputs, i.e. road classifications and vehicle speeds, can be found in Appendix C.

3. Meteorological Data

In re-evaluating the 1999 MOBOTOX5b modeling, DNR used the same MOBTOX5b meteorological inputs in MOBILE6.1 /6.2.

The 2002 meteorological data inputs to the MOBILE model included local temperature, absolute humidity, cloud cover percent, sunrise and sunset times. Temperature data were taken from the *Local Climatological Data Summary – Year 2002 for Huntsville, AL*.[16] To determine absolute humidity, DNR downloaded an Excel spreadsheet calculator from the Mobile Source Web site.[17] Temperature and relative humidity data were taken from the Climatological Data summary and input to the calculator to determine absolute humidity. Cloud cover percent,

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[16] *2002 Local Climatological Data: Annual Summary With Comparative Data- Huntsville, Alabama;* ISSN 0197-9485; National Oceanic and Atmospheric Administration, National Climatic Data Center,; Asheville, NC.

[17] The Excel spreadsheet is available on EPA's Office of Transportation and Air Quality website, and is included in the MOBILE6 Vehicle Emission Modeling Software section of the site. www.epa.gov/otaq/m6.htm.

sunrise and sunset times for north Alabama were taken from default data used in the Alabama MOBILE6 interface developed for the State of Alabama[18]. Supporting documentation for the 2002 meteorological inputs used in MOBILE6 can be found in Appendix D.

4. <u>*Fuel Parameters*</u>

In re-evaluating the 1999 MOBOTOX5b modeling, DNR used the fuel parameter data EPA had previously compiled for the 1996 base year summertime and winter modeling in developing emission factors for the SE as input to the MOBILE6.1/6.2 model. This data is included in Appendix E – 1996 Baseline Fuel Specifications.

MOBILE6.2 requires fuel parameter inputs for the following when calculating emission factors for HAPS: gas aromatic %, gas olefin %, gas benzene %, E200, and E300.
In an attempt to obtain data that would be representative of the North Alabama area, DNR contacted sources referenced in the MOBILE6.2 Technical Description Document.[19] Both the Alliance of Automobile Manufacturers and TRW Petroleum Technologies indicated that this information was available for large metropolitan areas only. Consequently, as an alternative to these sources, DNR examined fuel parameter summaries for conventional gasoline from several sources, and averaged the data for use in the MOBILE model. The sources from which this data was extracted included EPA's 1996 Baseline data for the Air Toxics Study,[20] EPA data on conventional gasoline parameters for year 2002,[21] Sunoco Oil Company data,[22] NESCAUM Study PADD III Areas data,[23] and information obtained from BP Oil Company via telephone conversation with a company engineer. A summary of the fuel parameter data used as 2002 model inputs and supporting documentation is included in Appendix E.

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[18] A project sponsored by the Alabama Department of Transportation; developed at the University of Central Florida and the University of Alabama – Birmingham.

[19] *Technical Description of Mobile6.2 and Guidance on Its Use for Emission Inventory Preparation (Draft Report);* EPA420-R-02-011; USEPA, Office of Air and Radiation; February 2002.

[20] See footnote 19, *supra*.

[21] *Conventional Gasoline Parameters by Reporting Year*; USEPA, Office of Transportation and Air Quality. This tabulated information can be accessed at OTAQ's website: www.epa.gov/otaq/regs/fuels/rfg/properf/cg-params97-02.htm.

[22] Doherty, H.M.; *Transportation Fuels;* July 2001. This Technical report can be accessed at Sunoco's website; www.sunocoinc.com/market/transportation_fuels.htm#.

[23] Marin, A., D. Kodjak, D. Brown and H. Rao; *Relative Cancer Risk of Reformulated Gasoline and Conventional Gasoline Sold in the Northeast;* Northeast States for Coordinated Air Use Management; August 1998.

III. RESULTS

A. 1999 Mobile Source HAP Emission Estimates

1. ***Mobile6.1 /6.2 Modeling Scenarios***

The 1999 MOBTOX5b modeling consisted of four model run-scenarios, each representing one of the four seasons (e.g. spring, summer, fall and winter). Similarly, seasonal input files were created for MOBILE6.1 /6.2 using the MOBTOX5b inputs as previously discussed. DNR used the MOBILE6.1/6.2 default particulate emission factor files as recommended in the Mobile User's Guide. A copy of the model input files for MOBTOX5b, and MOBILE6.1 /6.2 can be found in Appendix F. Also included are the output files for MOBILE6.1/6.2.

2. ***Data Summary***

The result of the modeling indicates that for benzene, acetaldehyde, formaldehyde and 1,3 butadiene, the use of MOBILE6.1/ 6.2 results in higher emission estimate for year 1999 than those obtained using MOBTOX5b. These results are shown in Table II. This observation is consistent with the limited data presented in EPA's Technical Document on MOBILE6.2 that states, " for these parameters MOBILE6.2 estimates higher emission factors in base years (i.e. 1990, 1996) with a convergence in emission factors by year 2020". The document further states, "this trend is primarily a result of changes in the total organic gas emission rates used in MOBILE6.2 versus those used in MOBTOX5b." [24]

Table II - 1999 MOBTOX5b Results Versus Those Obtained Using MOBILE6.1/ 6.2

HAP Emission Estimates Tons/ Year

HAP	MOBTOX5b	MOBILE6.1 6.2
Benzene	117.1	136.8
Acetaldehyde	12.7	16.1
Formaldehyde	36.0	46.1
1,3 Butadiene	16.4	20.3
Exhaust Diesel PM	36.9	29.6

The use of MOBILE6.1/6.2 resulted in lower diesel exhaust particulate emission estimates for year 1999 than those previously obtained using PART5. A closer examination of

[24] See footnote 19, supra.

the calculated emission factors indicates that MOBILE6 calculated a higher factor for LDDV (Light Duty Diesel Vehicles) and lower factors for the LDDT (Light Duty Diesel Trucks) and the combined HDDV (Heavy Duty Diesel Vehicles) categories. These results appear to be consistent with information provided in EPA's Technical Description document of MOBILE6.1, where EPA acknowledges differences in emission estimates resulting from the use of the two models. The Reference document further comments that "the principal reasons for these differences are changes in vehicle registration and technology distributions between PART5 and MOBILE6". [25]

B. 2002 Mobile Source HAP Emission Estimates

1. ***MOBILE6.1 /6.2 Modeling Scenarios***

The 2002 MOBILE6.1/6.2 modeling consisted of four basic model scenarios grouped by months based on fuel RVP, temperature and humidity. For each scenario, a model run was made at a speed of 12.9 mph (model default for local roads), and at the transportation network speeds for collectors, arterials, etc., as previously discussed. Copies of the model input and output files can be found in Appendix G.

2. ***Data Summary***

The 2002 emission estimates indicates a decrease in HAP emissions relative to 1999, as shown in Table III.

Table III - 1999 & 2002 On-Road Mobile Source HAP Emissions, Modeled Using MOBILE6.1/ 6.2

HAP Emission Estimates Tons/ Year

HAP	1999 Huntsville	2002 Huntsville
Benzene	136.8	114
Acetaldehyde	16.1	12
Formaldehyde	46.1	33
1,3 Butadiene	20.3	15
Acrolein	--	2
Exhaust Diesel PM	29.6	16.3

[25] *MOBILE6.1 Particulate Emission Factor Model Technical Description*; EPA420-R-03-001, USEPA, Office of Air and Radiation; January 2003.

C. Model Sensitivity Analysis: Effect of Local versus MOBILE6 Default VMT Fleet Mix

MOBILE6 emission factors vary significantly depending on the composition of the vehicle fleet. To evaluate the impact of using MOBILE6 default VMT fractions, DNR repeated the 2002 model runs using the same input files, minus the local VMT fractions used to characterize Huntsville's vehicle fleet.

The MOBILE6 default VMT fleet mix resulted in higher emission estimates for three of five HAPS, as shown in Table IV. However, for the organic HAPs, the results are rather close. The largest difference is roughly +12 %, for formaldehyde. Acetaldehyde emissions are roughly 8 % higher using the default MOBILE VMT mix, and benzene emissions are roughly 4 % lower using the MOBILE defaults. 1,3-butadiene and acrolein emissions are the same using the local VMT mix and the MOBILE defaults. Although the organic gas emission estimates are similar using the local VMT mix and MOBILE6 VMT mix defaults, the diesel particulate estimates using the MOBILE defaults differ dramatically. The estimate using the MOBILE default is 76.9 TPY and the estimate using the local vehicle mix is only 16.3 TPY. Thus, diesel particulate emissions estimates using the MOBILE defaults are nearly 5X higher than the emissions estimate based on local vehicle registration data.

Table IV - Huntsville 2002 On-Road Mobile Source HAP Emission Estimates Based on Local Versus MOBILE6 Default VMT Mix

HAP	2002 Local Registration VMT Mix (TPY)	2002 MOBILE6 Default VMT Mix (TPY)
Benzene	114	109
Acetaldehyde	12	13
Formaldehyde	33	37
1,3 Butadiene	15	15
Acrolein	2	2
Exhaust Diesel PM	16.3	76.9

A review of the model output data indicates that the MOBILE6 default fleet mix resulted in higher emission factors for the HDDV category. Huntsville has a much smaller fraction of these vehicles in the fleet as compared to the model defaults, as shown in Table V. However, for the HDGV category, the MOBILE6 default fleet mix yielded lower emission factors because Huntsville's fleet has a slightly higher proportion of these vehicles than the MOBILE6 default, as also shown in Table V. The differences in the emission estimates obtained using the two VMT mixes result primarily from different relative contributions to the total fleet by these two categories of vehicles, i.e. Heavy Duty Gas Vehicles, and Heavy Duty Diesel Vehicles.

Emission factors and emission estimates for other vehicle categories were comparable using the default versus local VMT mix. The huge disparity in diesel particulate emissions estimates is the direct result of the large difference between the contribution of HDDV's to total VMT in the MOBILE default relative to their contribution based on local vehicle registration data. This category of vehicles totally dominates the on-road diesel particulate emission inventory.

Table V - MOBILE6 Default VMT Mix (Distribution) Versus Local VMT Mix

	Vehicle Type							
VMT Mix	**LDGV**	**LDGT12**	**LDGT34**	**HDGV**	**LDDV**	**LDDT**	**HDDV**	**MC**
M6 Default	**0.4568**	**0.3091**	**0.1063**	**0.0360**	**0.0008**	**0.0017**	**0.0833**	**0.0060**
Local	**0.4731**	**0.3216**	**0.1086**	**0.0509**	**0.0008**	**0.0017**	**0.0285**	**0.0148**

Although criteria pollutant emissions are not the subject of this Report, considerable differences were also noted in the emission estimates for total particulate and NOx when using the MOBILE6 default fleet mix. The large difference in total particulate emission estimates is due to the different relative contributions of HDDV's, as discussed above. This should be rather obvious. Since the MOBILE6 default fleet mix contains nearly three times as many of these vehicles than the local fleet, emission estimates for exhaust particulate would be expected to be dramatically higher, as is shown in Table IV. In addition to huge differences in the emissions estimates for particulate matter, there were significant differences with respect to NOx emissions. HDDV are high emitters of both particulate and NOx. The dramatic effect of VMT mix on on-road criteria pollutant emissions estimates was noted and discussed briefly in a Sensitivity Analysis of MOBILE6 performed by Tang, Roberts and Ho. After examining the effect of varying the VMT fractions of the HDV8B and HDV8A categories, and the LDT4 and HDV2B categories, the authors concluded, "Emission rates for all three pollutant emission rates [the criteria pollutants, CO, NO_x, and PM] are exceedingly sensitive to changes in VMT traveled by the HDV8A and HDV8B vehicles. This phenomenon indicates that VMT allocation even between closely related HDV's is still critical in the emission rate modeling." [26]

The results of this analysis serve to underscore the importance of characterizing the vehicle fleet of the model area to the greatest extent practicable. The MOBILE model is very sensitive to changes in VMT fractions, with resultant changes in calculated emission factors.

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[26] *Sensitivity Analysis of MOBILE6 Motor Vehicle Emission Factor Model*; Tianija Tang, Mike Roberts, and Cecilia Ho; U.S. Department of Transportation – Federal Highway Administration – www.fhwa.dot.gov/resourcecenter/airq_tinja.htm

IV. SUMMARY AND CONCLUSIONS

The results of the modeling for 1999 using MOBTOX5b and PART 5, and those obtained using MOBILE6 are compared in Table II. Relative to the results obtained using MOBTOX5b, the use of MOBILE6.1/ 6.2 resulted in higher 1999 on-road mobile source emission estimates for the HAPS acetaldehyde, benzene, 1,3-butadiene, and formaldehyde. These results are consistent with information contained in EPA's Technical Description on MOBILE6.2, which states "MOBILE6 estimates higher emission factors in base years (i.e. 1990, 1996) with a convergence in emission factors by year 2020. This trend is primarily the result of changes in the TOG (Total Organic Gas) emission rates used in MOBILE6.2, versus those used in MOBTOX5b." [27] On the other hand, 1999 diesel exhaust particulate emission estimates were lower using MOBILE6.1/6.2 than those obtained using PART5. According to EPA's Technical Document on MOBILE6.1, the principal reason for these differences are changes in vehicle registration and technology distribution between PART5 and MOBILE6.[28]

Of particular interest was the result of the sensitivity analysis using the MOBILE6 default VMT mix. The magnitude of the differences noted for some pollutants underscores the importance of characterizing the vehicle fleet of the modeled area to the greatest extent practicable. The model is particularly sensitive to changes in the fleet mix that involve the classes of heavy-duty gasoline and diesel vehicles. These are precisely the classes of vehicles that showed the greatest differences between the MOBILE defaults and the local registration data, and the resultant emissions estimates for diesel particulate were nearly five times higher using the MOBILE defaults than the diesel PM estimates using the local vehicle registration data. As shown in Table IV, on-road diesel particulate emissions were estimated at 76.9 TPY using the MOBILE default VMT mix, and only 16.3 TPY using the local vehicle registration data to characterize VMT.

It was difficult to decide whether to use local registration data for the heavy-duty vehicles, or to rely on the MOBILE defaults, at least with respect to these classes of vehicles. The significantly lower percentages of these vehicles reflected in local registration data than in the MOBILE defaults raises possible concerns regarding the validity of the registration data in this context. Trucks used to transport goods over the road certainly pass through Huntsville, but how many of these vehicles would actually be registered in Madison County? This consideration argues for the use of the MOBILE defaults for at least some classes of heavy-duty vehicles. On the other hand, the percentage of "18-wheelers" on the road in Huntsville and Madison County is probably atypically low. I-65, a north-south freeway that extends from Mobile, Alabama to Chicago, Illinois, is heavily used by long-distance truckers. Although connected to Huntsville by an interstate spur (I-565), no part of I-65 is located in Madison County. Thus, most of the north-south interstate truck traffic never enters Madison County. Most of the truck traffic travels just to the west of the Madison County line (in Limestone County) on I-65. Similarly, there is no

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[27] Reference Section 4.1 (page 18) of the *Technical Description of the Toxics Module for MOBILE6.2 and Guidance on its Use for Emission Inventory Preparation;* EPA420-R-02-029; USEPA, Office of Air & Radiation; November 2002.

[28] Reference the Introduction section of the *MOBILE6.1Particluate Emission Factor Model Technical Description: Final Report;* EPA 420-R-03-001; USEPA Office of Air & Radiation; January 2003

east-west interstate traversing Madison County. I-565 extends east from I-65, but terminates at U.S Hwy 72 at the eastern edge of Huntsville. I-565 and Hwy 72 are certainly utilized by long-distance truckers, but many may prefer to use I-40 through middle Tennessee or I-20, which passes through Birmingham roughly 100 miles south of Huntsville. These considerations argue for the use of the local vehicle registration data in characterizing the heavy-duty vehicle contributions to VMT in Huntsville and Madison County. After weighing these countervailing considerations, DNR chose to use the local vehicle registration data, recognizing that this may result in some underestimation of mobile source emissions.

Some brief mention should also be made of the low contribution of buses to total VMT when using the local registration data as opposed to the MOBILE6 default VMT mix. Again, the VMT mix based on local registration data assigns only 0.04 % of the total VMT to bus traffic, whereas the MOBILE default VMT mix assigns 0.48 % of total VMT to buses. The small number of buses operated by Huntsville's Public Transit Division, and the relatively small number of school children provided with bus service in the Huntsville area tend to support the conclusion that the local vehicle registration data characterizes the contribution of buses to total VMT far more accurately than the MOBILE6 defaults. Although DNR wrestled with the decision to use local registration data to characterize VMT contributions by the HDV8A and HDV8B vehicle categories, the question of whether to use local registration data to characterize bus VMT posed no such dilemma.

The 2002 emission estimates for Huntsville indicate a decrease in on-road HAP emissions relative to 1999. The 1999 and 2002 on-road mobile source emissions inventories are summarized in Table III. Examination of Table III reveals rather dramatic decreases in all of the modeled HAPs. The modeling results indicate a 16.7 % decrease in benzene emissions (from 136.8 TPY to 114 TPY) from 1999 to 2002. Even larger relative reductions are noted for acetaldehyde (27.3 %, from 16.1 TPY to 12 TPY), formaldehyde (28.4 %, from 46.1 TPY to 33 TPY), and 1,3-butadiene (26.1 %, from 20.3 TPY to 15 TPY). The most dramatic apparent reduction from 1999 to 2002 involves diesel particulate, for which the modeling results show an incredible 57.1 % reduction, from 29.6 TPY in 1999 to 12.7 TPY in 2002.

Some decrease in the emission factors generated by MOBILE is to be expected due to continued fleet turnover, i.e. an increase in the relative number of newer, lower emitting vehicles in the vehicle fleet. However, this effect would be relatively small over a three-year period. Moreover, the effect of fleet turnover would largely be offset by increases in VMT. As shown in Table I, in-City daily VMT increased from 4.77 million miles to 5.14 million miles, an increase of 7.7 %. [Recall that traffic count data are updated by Traffic Engineering biennially, and 2003 VMT was used to model 2002 mobile source emissions.] It seems the increased VMT would either largely negate, or even overwhelm any reduction in emissions resulting from fleet turnover. These facts suggest that the apparent dramatic reductions in on-road mobile source HAP emissions from 1999 to 2002 are actually an artifact of the modeling methodology employed.

The MOBILE6 model is very sensitive to changes in the VMT mix. This fact is dramatically evidenced by both DNR's cursory sensitivity analysis and the more thorough sensitivity analysis performed by EPA. As emphasized previously, use of the local vehicle registration data to characterize VMT contributions by HDDV's resulted in diesel particulate emission estimates that are only a small fraction of those obtained using the MOBILE defaults (16.3 TPY, which is only 21 % of the value obtained using the MOBILE default VMT mix, i.e. 76.9 TPY).

This raises the possibility that at least some of the apparent reduction in mobile source HAP emissions from 1999 to 2002 could have resulted from changes in the allocation of vehicles among the various MOBILE6 vehicle classes. As discussed previously, the format of the local vehicle registration data included only four vehicle categories for 1999, but was expanded to 11 vehicle categories in 2002. In converting these data sets to the format required for the MOBILE6 input files, shifts in the relative number of vehicles in the various classes could have resulted. In fact, this is precisely what happened.

In 1999, the County vehicle registration office provided DNR with a breakdown of registered vehicles into only four categories. These were passenger vehicles, light & medium trucks, heavy trucks, and motorcycles. In expanding these registration data to the 8 classes of vehicles employed as MOBTOX5b inputs, the default VMT distribution was used to expand the "heavy trucks" category in the local registration data to the "HDGV" and "HDDV" categories used by MOBTOX5b. Thus, although the total number of vehicles in these categories was much lower than in the default VMT mix, the relative numbers of gasoline vehicles and diesel vehicles were the same as in the default mix with respect to each other. The procedures for expanding the MOBTOX5b categories to the 16 categories used by MOBILE simply took this approach one step further. As a result, the population of heavy trucks in Madison County mirrored the VMT mix in MOBILE, even though the total numbers were much smaller. In contrast, the County provided more detailed information with respect to the 2002 vehicle registration data, and included the actual numbers of vehicles in the HDV2B, HDV3, HDV4, HDV5, HDV6, HDV8A, and HDV8B categories. (Reference Appendix B). As a result, the apportionment of VMT among the vehicle classes included within the general category of "HDDV's" differs dramatically in the 1999 and 2002 modeling runs.

Not only does the local vehicle registration data include a much lower total number of "heavy trucks," but the relative numbers of vehicles in each category are strongly skewed toward the small vehicles in the 2002 modeling. A careful examination of the information in Appendix B illustrates this fact. In the 1999 model input, the VMT allocated to vehicles in classes HDV2B, HDV3, HDV4, and HDV5 was 1.4 % of total VMT, while the VMT allocated to vehicles in the HDV6, HDV7, HDV8A and HDV8B classes is 2.0 % of the VMT total. In contrast, in the 2002 modeling, 7.0 % of the VMT is contributed by vehicles in classes HDV2B, HDV3, HDV4, and HDV5, and only 1.0 % of the VMT is allocated to vehicles in the HDV6, HDV7, HDV8A and HDV8B. Madison County actually has a slightly *higher* percentage of vehicles than the MOBILE default for HDV2B vehicles, almost the same percentage of HDV3 vehicles, and differences become progressively more dramatic in moving toward the heavier vehicles, culminating in the very large differences for HDV8A and HDV8B vehicles (In Madison County, these classes account for only 0.3 % of the vehicles, whereas they contribute 1.95 % of the total VMT in the MOBILE default VMT mix).

As emphasized repeatedly, MOBILE6 diesel particulate emissions estimates are very sensitive to changes in the VMT mix among the HDDV's, and the apparent dramatic reduction in diesel particulate emissions from 1999 to 2002 is due entirely to the changes in VMT mix for the two modeling years. This is an artifact of the format in which the vehicle registration data was provided to DNR and does not reflect an actual reduction in on-road diesel PM emissions.

The apparent reductions in on-road organic HAP emissions are not as dramatic as the apparent reductions in diesel PM from 1999 to 2002, but are still very significant. As discussed in some detail above, these apparent reductions ranged from roughly 17 % for benzene to over 28 % for formaldehyde. These apparent reductions are also an artifact of the way the modeling was performed and do not reflect actual emission reductions. In the case of the organic HAPs, differences in modeled speeds between the 1999 and 2002 modeling runs account for the significant differences in organic HAP emissions. Unlike diesel PM, which is relatively insensitive to changes in vehicle speed (but extraordinarily sensitive to VMT mix), organic HAP emission factors are strongly influenced by vehicle speed.

In the modeling for 1999, the MOBTOX5b default vehicle speed for the Southeast, i.e. a speed of 19.6 mph, was used as input to the MOBILE6 model. This approach allowed a direct comparison of the MOBTOX5b and MOBILE6 modeling results for 1999. However, in the modeling for 2002, the vehicle speed inputs were taken from transportation modeling results obtained by the Huntsville Planning Department. As discussed earlier, the MOBILE6 default speed of 12.9 mph was used for local roads, which are not included in the transportation network modeling, but collectors and arterials were modeled at significantly higher speeds, 34.8 mph and 37.4 mph, respectively. This is the most dramatic difference in the modeling performed for 1999 and 2002. MOBILE6 organic HAP emission factors decrease rather dramatically with increasing vehicle speed. E.g. the benzene composite emission factor (averaged over all vehicle classes) is 0.079 g/mi for a speed of 12.9 mph and only 0.056 g/mi for a speed of 35 mph, a difference of –30 %. This effect is similar for all of the organic HAPs. It seems very clear that the difference in vehicle speed inputs to the 1999 and 2002 modeling is the principal reason for the apparent reduction in mobile source HAP emissions from 1999 to 2002.

In general, the MOBILE6 model is viewed as a substantial improvement over MOBTOX5b and PART5 in estimating mobile source HAP emissions. The model is extremely sensitive to VMT mix with respect to diesel particulate emissions, but this is probably an accurate reflection of reality. The larger diesel trucks contribute disproportionately to total diesel PM emissions, and VMT shifts among the various HDV categories no doubt really do result in dramatic changes to total diesel PM emissions. Similarly, the sensitivity of the MOBILE6 model to vehicle speed with respect to organic HAP emission factors seems realistic. The sensitivity of the model underscores the need for accurate information regarding both VMT mix and travel speeds. If accurate emission estimates are desired, then these model input parameters must also be accurate. Of course, precise characterization of the fleet mix, and the resultant VMT mix, is generally not practicable when dealing with vehicle registration data. Similarly, there is inherent inaccuracy in using average network speeds for various road classifications generated by a transportation model.

Despite these limitations in the accuracy of input data, and the sensitivity of the MOBILE6 model to these parameters, the 2002 on-road mobile source HAP emission inventory for Huntsville is viewed as a substantial improvement over the 1999 inventory. Although not perfect, the use of transportation network modeling to estimate vehicle speeds on various types of roads, and using the actual VMT on those individual roads to estimate emissions is certainly more accurate than using a single speed class. Similarly, the use of local vehicle registration data to characterize the VMT mix is generally preferable to using national default distributions. However, DNR retains misgivings regarding the on-road diesel PM emissions estimates for Huntsville. They are probably understated. On the other hand, the use of the MOBILE default VMT mix would probably result in a significant overestimation of on-road diesel PM emissions for the Huntsville area. DNR ultimately concluded that use of the default VMT mix would probably result in overestimation of on-road diesel PM emissions to a greater extent than use of the local vehicle registration data would underestimate these emissions. The models have become more sophisticated, but the accuracy of their results continues to rely heavily on the accuracy of the input data and the judgment of the modeler.

In more general terms, the effort under this supplemental grant has provided DNR staff with a better understanding of mobile source emissions modeling, and a better understanding of mobile source emissions sources in the Huntsville area. This was a primary goal of the effort, and has undoubtedly been achieved.